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Lab Streaming Layer-Enabled Myo Data Collection Software User Manual

by Michael H Lee

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Lab Streaming Layer-Enabled Myo Data Collection Software User Manual

by Michael H Lee

Computational and Information Sciences Directorate, ARL

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1. Introduction

The Myo Data Collection Software is a simple Java console application that records various sensor data from a Myo armband, which includes an inertial measurement unit sensor, gyroscope, accelerometer, and electromyography (EMG) sensor. The software can save the data to a comma-separated value (CSV) file or stream the data to a lab streaming layer (LSL)-based data synchronizing repository called Lab Recorder. All components of the Myo Data Collection Software are briefly described in the first section of this report. Installation and operation of the software are described in the second half of the report. An example of the Myo Data Collection Software printout is displayed as follows:

```
YYYY-MM-DD
HH:MM:SS.SSS,ROLL,PITCH,YAW,GYRO_X_DEG/SEC,GYRO_Y_DEG/SEC,GYRO_Z_
DEG/SEC,ACCEL_X_G,ACCEL_Y_G,ACCEL_Z_G,POSE,EMG_CH1,EMG_CH2,EMG_CH
3,EMG_CH4,EMG_CH5,EMG_CH6,EMG_CH7,EMG_CH8
2017-02-07 15:46:24.052,69.111894,78.690268,80.775977,-
0.375000,0.625000,1.250000,0.190918,-0.654297,0.721680,REST,1,0,-
2,-2,-3,-1,-1,-1
2017-02-07 15:46:24.154,69.066327,78.880307,80.838109,-
0.875000,0.312500,2.312500,0.187500,-0.654297,0.720215,REST,-1,-
2,-1,-2,-2,-1,-1,0
```

The Myo is a commercially available Bluetooth armband developed by Thalmic Labs. It is capable of transmitting various positioning and pose information to user-developed software. The Myo detects 5 poses: Fingers Spread, Wave In, Wave Out, Fist, and Double Tap. Positioning data (e.g., roll, pitch, yaw, acceleration, etc.) are accessed using an accompanying software development kit (SDK) from Thalmic Labs for multiple operating system platforms. These data can be used to train classifiers to predict human hand gestures.* Further details and specifications are available on the company website: <https://www.myo.com/techspecs>.

* Lee M, Rao N. Hand gesture data collection procedure using a Myo armband for machine learning. Army Research Laboratory (US): Adelphi (MD); 2015 Sep. Report No.: ARL-TN-0699.



Fig. 1 The Myo armband by Thalmic Labs (image from <http://www.tumsenahopayga.com/wp-content/uploads/2015/12/Myo-By-Thalmic-Labs-Gesture-Sensor-Controller-Armad-For-iPhone-Android-Mac-and-PC.jpg>)

LSL is an open source system for transmitting time-series data over a local network. LSL handles the networking, time-synchronization, (near-) real-time access as well as, optionally, the centralized collection, viewing, and recording of the data.[†] A potential use of LSL is for human information researchers to implement intricate time-series data collection (e.g., brain activity, heart activity, muscle activity) using the LSL application programming interface (API). Time-synchronized data from one or more stream sources are collected in a separate repository called the Lab Recorder, which is part of the LSL software suite, and saved to a single extensible data format (XDF) file. Once the time-series data are collected in a Lab Recorder XDF file, users will be able to query for data within a precise range of time. The Lab Recorder source code and the executable are downloadable from <https://github.com/scn/labstreaminglayer/wiki/LabRecorder.wiki>.

2. Software Setup

This section describes steps required to set up the Myo Data Collection Software. Dependent third-party software is also identified in this section, but instruction for the installation and setup of that software is not described. The Myo Data Collection Software distribution includes the following libraries:

[†] <https://github.com/scn/labstreaminglayer>


```
MyoCollectData.jar - Myo Data Collection Software main
executable.
libls132.dll - LSL library for 32-bit system.
libls164.dll - LSL library for 64-bit system.
MyoResources - Folder containing Myo libraries for various
platforms.
```

- 1) Download Lab Recorder from an LSL distribution site:

At the time of writing this report, Lab Recorder is available to download from <ftp://sccn.ucsd.edu/pub/software/LSL/Apps/LabRecorder-1.12b.zip>

The zip file contains the C++ project files and a Lab Recorder executable file.

The only dependency is that the Lab Recorder requires Python 2.6 or greater to run.

- 2) Install the Myo standard software suite (e.g., Armband Manager, Application Manger, Myo Connect) that was included with the Myo armband.
- 3) Copy the Myo Data Collection Software Java archive (JAR) file to a desired location.

Ex: C:\arl\MyoCollectData.jar

- 4) Copy the Myo's resource folder, "MyoResources", to a desired location.

The "MyoResources" folder contains the Myo dynamic-link libraries (dlls) needed by the Myo Data Collection Software.

The dlls are grouped by OS platforms (e.g., osx, Win32, x64) in corresponding subdirectories.

Note the path to the dll that targets the developer's OS platform.

Ex: C:\arl\MyoResources\x64\ (For 64-bit Windows)

- 5) Copy the LSL dlls (libls132.dll and libls164.dll) to the same location where the Myo Data Collection Software JAR was placed.

Ex: C:\arl\libls132.dll

C:\arl\libls164.dll

The LSL Java API used in the Myo Data Collection Software requires these native LSL dll libraries.

These dlls can be placed in various locations depending on the developer's computer, but the simplest location is the same folder as the Myo Data Collection Software JAR.

If the JAR executable cannot find the referenced dlls, it will generate an error:

```
Unable to load library 'libls164.dll': Native library (win32-x86-64/libls164.dll) not found in resource path  
([file:/C:/some/path/xyz/, file:/C:/another/path/jna-4.2.2.jar])
```

In an unlikely event that a similar error message is thrown, simply copy the dlls into the identified folder.

Note: The LSL dlls cannot be copied to the Myo subdirectories. The LSL API looks for its dlls in a specific location.

3. Software Execution and Command Arguments

The Myo Data Collection Software can run independently without the Lab Recorder and save the Myo movement data to a CSV file. It can also be configured to run with LSL enabled and stream the Myo movement data to a Lab Recorder. In either mode of operation, the Myo Data Collection Software saves the Myo movement data to a CSV file.

- 1) Wear the Myo armband according to the manufacturer's instructions and verify that the developer's computer recognizes the armband before continuing.

The Myo status graphic will change as the Myo prepares itself for use (Figs. 2–4).



Fig. 2 Initial status message when the user wears the armband

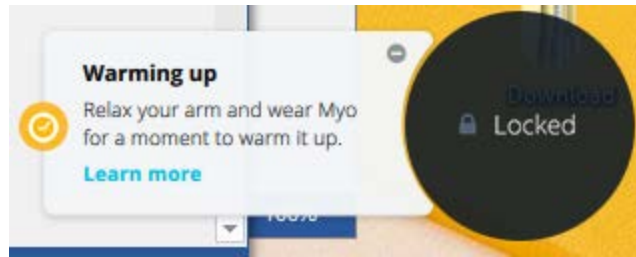


Fig. 3 Status message given while the armband warms up

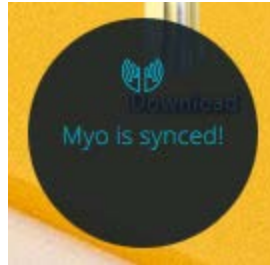


Fig. 4 Status message after the Myo is warmed up and ready for use

- 2) Open a console to where the Myo Data Collection Software JAR file is located (Ex: C:\arl\).

Build the Java command string using the following argument definitions.

- **“-Djava.library.path”**–Full path to the Myo dlls selected from step #4 in the previous section.

Ex: -Djava.library.path=C:\arl\MyoResources\x64\

- **“Output”**–Full path to where to create the CSV output file.

If the “Output” argument is not provided, a unique output CSV file (named according to time format YYYY-mm-dd HHMMSS.csv) will be automatically created in the same folder of the JAR.

Ex: Output=C:\arl\output.csv

- **“SPS”**–Samples Per Second. Defines how many samples should be recorded in 1 s.

If SPS is not provided, default value 10 will be used.

Ex: SPS=10

- **“SendDataToLSL”** – True/False Boolean value that defines whether the Myo Data Collection Software should attempt to stream the Myo movement data to the Lab Recorder.

Ex: SendDataToLSL=True

The following is an example Java command to execute the Myo Data Collection Software:

```
java -Djava.library.path=C:\ar1\MyoResources\x64\ -jar
MyoCollectData.jar Output=C:\ar1\output.csv SPS=10
SendDataToLSL=True
```

The Myo Data Collection Software will begin printing initialization updates and the current Myo movement data to the console.

```
System Properties from VM Arguments
    Name=java.library.path, Value=C:\ar1\MyoResources\x64\

Program Arguments:

[Output=C:\ar1\output.csv]
Output file path set to: C:\ar1\output.csv
C:\ar1\output.csv already exists. Deleting before continuing...

[SPS=10]
Sampling Rate set to: 10 per Second

[SendDataToLSL=True]
Will attempt to connect to LSL.

Attempting to find a Myo...
Connected to a Myo armband!

Attempting to connect to LSL. Creating a new StreamInfo...
Creating a LSLStreamOutlet...
Successfully connected to LSL. StreamOutlet Info:
edu.ucsd.sccn.LSL$StreamInfo@6193b845

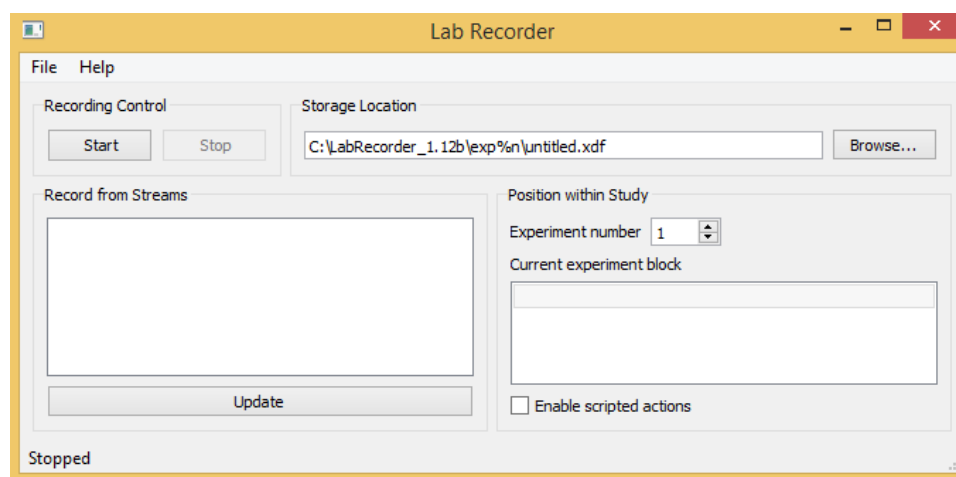
YYYY-MM-DD
HH:MM:SS.SSS,ROLL,PITCH,YAW,GYRO_X_DEG/SEC,GYRO_Y_DEG/SEC,GYRO_Z_
DEG/SEC,ACCEL_X_G,ACCEL_Y_G,ACCEL_Z_G,POSE,EMG_CH1,EMG_CH2,EMG_CH
3,EMG_CH4,EMG_CH5,EMG_CH6,EMG_CH7,EMG_CH8
2017-02-07 15:46:24.052,69.111894,78.690268,80.775977,-
0.375000,0.625000,1.250000,0.190918,-0.654297,0.721680,REST,1,0,-
2,-2,-3,-1,-1,-1
2017-02-07 15:46:24.154,69.066327,78.880307,80.838109,-
0.875000,0.312500,2.312500,0.187500,-0.654297,0.720215,REST,-1,-
2,-1,-2,-2,-1,-1,0
```

The Myo Data Collection Software can be stopped by pressing “Control + C”.

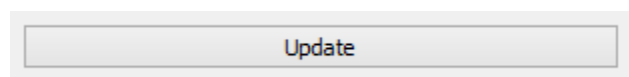
- 3) Navigate to the path where the Lab Recorder was installed and start “LabRecorder.exe”.

Ex: C:\LabRecorder_1.12b\LabRecorder.exe

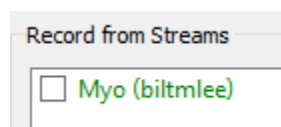
Change the path where the XDF file will be saved.



Click on the “Update” button to see a list of available data sources.

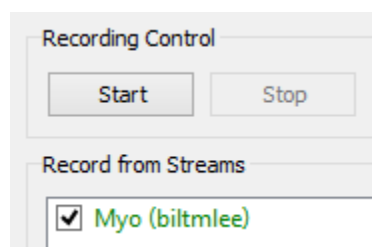


If the data source application is currently streaming data, the “Record from Streams” window will update with the source ID.

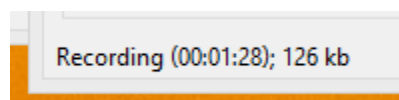


Click on the “Myo [Source ID]” checkbox to select that data source.

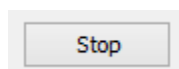
Click on the “Start” button to begin recording the Myo movements to file.



The bottom status indicator will show the recording progress—how long it has been recording and how much data it has recorded.



When the user has finished with the data collection, click the “Stop” button to stop receiving the data stream and close the XDF file.



4. Output Files

The Myo Data Collection Software has 2 data outflows (not including the Lab Recorder XDF output file):

- 1) Data printout to the console
- 2) Data saved as a CSV file

Examples of each outflow are included as an appendixes of this report.

The 2 data outputs are the same. The only difference is that the CSV file does not include the software settings information in the beginning. Table 1 lists the attributes that are included in the output file along with supplemental information about the attribute.

Table 1 Attributes included in the Myo Data Collection Software output file

| CSV Column Name | Note |
|----------------------------|---|
| YYYY-MM-DD HH:MM:SS.SSS | Time stamp when the sample was recorded. Ex: 2017-01-12 16:47:08.128 |
| | Time stamp is not included in the data streamed to the LSL Lab Recorder. |
| ROLL | Part of the Myo Orientation sensor data. The Quaternion variable provided by the Myo SDK is used to derive this value. $\text{Quaternion normalized} = \text{rotation.normalized}();$ $\text{double roll} = \text{Math.atan2}(2.0f * (\text{normalized.getW}() * \text{normalized.getX}() + \text{normalized.getY}() * \text{normalized.getZ}()), 1.0f - 2.0f * (\text{normalized.getX}() * \text{normalized.getX}() + \text{normalized.getY}() * \text{normalized.getY}()));$ $\text{mRollW} = ((\text{roll} + \text{Math.PI}) / (\text{Math.PI} * 2.0) * 180);$ |

Table 1 Attributes included in the Myo Data Collection Software output file (continued)

| CSV Column Name | Note |
|------------------------|--|
| PITCH | <p>Part of the Myo Orientation sensor data. The Quaternion variable provided by the Myo SDK is used to derive this value.</p> <pre>Quaternion normalized = rotation.normalized(); double pitch = Math.asin(2.0f * (normalized.getW() * normalized.getY() - normalized.getZ() * normalized.getX())); mPitchW = ((pitch + Math.PI / 2.0) / Math.PI * 180);</pre> |
| YAW | <p>Part of the Myo Orientation sensor data. The Quaternion variable provided by the Myo SDK is used to derive this value.</p> <pre>Quaternion normalized = rotation.normalized(); double yaw = Math.atan2(2.0f * (normalized.getW() * normalized.getZ() + normalized.getX() * normalized.getY()), 1.0f - 2.0f * (normalized.getY() * normalized.getY() + normalized.getZ() * normalized.getZ())); mYawW = ((yaw + Math.PI) / (Math.PI * 2.0) * 180);</pre> |
| GYRO_X_DEG/SEC | <p>Myo Gyroscope data (X Axis), represented in degrees/sec. The Myo SDK provides Gyroscope data normalized and unnormalized. This value is the unnormalized Gyroscope data.</p> |
| GYRO_Y_DEG/SEC | <p>Myo Gyroscope data (Y Axis), represented in degrees/sec. The Myo SDK provides Gyroscope data normalized and unnormalized. This value is the unnormalized Gyroscope data.</p> |

Table 1 Attributes included in the Myo Data Collection Software output file (continued)

| CSV Column Name | Note |
|------------------------|---|
| GYRO_Z_DEG/SEC | Myo Gyroscope data (Z Axis), represented in degrees/sec. The Myo SDK provides Gyroscope data normalized and unnormalized. This value is the unnormalized Gyroscope data. |
| ACCEL_X_G | Myo Accelerometer data (X Axis), represented in units of g. The Myo SDK provides Accelerometer data normalized and unnormalized. This value is the unnormalized Accelerometer data. |
| ACCEL_Y_G | Myo Accelerometer data (Y Axis), represented in units of g. The Myo SDK provides Accelerometer data normalized and unnormalized. This value is the unnormalized Accelerometer data. |
| ACCEL_Z_G | Myo Accelerometer data (Z Axis), represented in units of g. The Myo SDK provides Accelerometer data normalized and unnormalized. This value is the unnormalized Accelerometer data. |
| POSE | Hand Pose (1 out of the 7 poses defined by Thalmic Labs) the Myo detects when the sample was recorded. Choices are DOUBLE TAP, FINGERS SPREAD, FIST, REST, UNKNOWN, WAVE IN, and WAVE OUT. In most cases, the Pose value will be “REST”. |
| EMG_CH1 | Myo Electromyography data (Pod #1). |
| EMG_CH2 | Myo Electromyography data (Pod #2). |
| EMG_CH3 | Myo Electromyography data (Pod #3). |
| EMG_CH4 | Myo Electromyography data (Pod #4). |
| EMG_CH5 | Myo Electromyography data (Pod #5). |
| EMG_CH6 | Myo Electromyography data (Pod #6). |
| EMG_CH7 | Myo Electromyography data (Pod #7). |
| EMG_CH8 | Myo Electromyography data (Pod #8). |

If the “SendDataToLSL” option is enabled and the Lab Recorder is used, a third output—an XDF file—is created.

The primary difference in the XDF file is in the Pose channel. Pose strings (e.g., “REST”, “FIST”, “WAVE IN”) are represented as numeric values rather than as strings. The following conversion map shows all available pose and their corresponding numeric values:

DOUBLE TAP -> 1
FINGERS SPREAD -> 2
FIST -> 3
REST -> 4
UNKNOWN -> 5
WAVE IN -> 6
WAVE OUT -> 7

An XDF file is not readable in a standard text reader application. A user must implement an XDF data reader in order to view the contents.

5. Conclusion

This report described the steps required to set up the Myo Data Collection Software and described the configurations to run the program. In addition to the CSV output file generated by the Myo Data Collection Software, it is able to stream the Myo movement data (orientation, gyroscope, and accelerometer) and EMG data to a LSL-based data synchronization component called Lab Recorder. Collecting data from physiological sensors, such as the Myo, is the first step in researching human information. An example use of Myo movement data is training classifiers to predict human gestures.

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Appendix A. Example Console Output

```

System Properties from VM Arguments
    Name=java.library.path, Value=C:\arl\MyoResources\x64\

Program Arguments:

[Output=C:\arl\output.csv]
Output file path set to: C:\arl\output.csv
C:\arl\output.csv already exists. Deleting before continuing...

[SPS=10]
Sampling Rate set to: 10 per Second

[SendDataToLSL=True]
Will attempt to connect to LSL.

Attempting to find a Myo...
Connected to a Myo armband!

Attempting to connect to LSL. Creating a new StreamInfo...
Creating a LSLStreamOutlet...
Successfully connected to LSL. StreamOutlet Info:
edu.ucsd.sccn.LSL$StreamInfo@6193b845

YYYY-MM-DD
HH:MM:SS.SSS,ROLL,PITCH,YAW,GYRO_X_DEG/SEC,GYRO_Y_DEG/SEC,GYRO_Z_
DEG/SEC,ACCEL_X_G,ACCEL_Y_G,ACCEL_Z_G,POSE,EMG_CH1,EMG_CH2,EMG_CH
3,EMG_CH4,EMG_CH5,EMG_CH6,EMG_CH7,EMG_CH8
2017-02-07 15:46:24.052,69.111894,78.690268,80.775977,-
0.375000,0.625000,1.250000,0.190918,-0.654297,0.721680,REST,1,0,-
2,-2,-3,-1,-1,-1
2017-02-07 15:46:24.154,69.066327,78.880307,80.838109,-
0.875000,0.312500,2.312500,0.187500,-0.654297,0.720215,REST,-1,-
2,-1,-2,-2,-1,-1,0
2017-02-07 15:46:24.255,69.195277,79.016308,80.965627,14.312500,-
5.375000,-0.687500,0.166504,-0.614258,0.745605,REST,72,-9,-3,-
12,-6,-30,1,45
2017-02-07 15:46:24.355,68.443448,78.639507,79.748023,-
83.750000,-14.062500,0.375000,0.422852,-1.167969,0.384766,REST,-
36,-74,0,8,9,-7,95,-98
2017-02-07
15:46:24.455,68.955867,79.102875,79.725088,13.187500,2.875000,-
2.000000,0.173828,-0.701660,0.739258,WAVE_IN,-
11,7,33,12,8,31,70,-37
2017-02-07 15:46:24.555,68.851457,79.555237,79.805152,-
0.375000,2.125000,0.937500,0.152344,-
0.671875,0.721680,WAVE_IN,73,27,-3,1,-1,-38,14,-11
2017-02-07 15:46:24.656,68.875371,79.537099,79.807765,-
2.937500,1.187500,-0.062500,0.189941,-
0.632324,0.735352,WAVE_IN,18,14,-4,-3,-8,-19,-43,-48
2017-02-07
15:46:24.757,68.804416,79.635662,79.740990,0.562500,1.875000,1.68
7500,0.174805,-0.672852,0.735840,WAVE_IN,-23,-12,0,-3,0,-18,12,-
84

```

2017-02-07 15:46:24.857,68.903215,79.756034,79.743440,-
 1.062500,0.937500,-0.687500,0.176758,-
 0.663086,0.734863,WAVE_IN,33,-11,31,6,7,2,-28,56
 2017-02-07 15:46:24.957,68.850674,79.703714,79.696705,-
 3.125000,0.125000,-1.687500,0.183594,-0.670898,0.745117,WAVE_IN,-
 47,-12,-113,-9,-11,-70,-32,-33
 2017-02-07 15:46:25.057,68.800025,79.665062,79.666306,-
 3.187500,0.375000,-1.812500,0.182617,-
 0.650879,0.733887,WAVE_IN,38,-17,29,-5,-6,12,2,-5
 2017-02-07 15:46:25.157,68.713604,79.552580,79.573293,-
 3.125000,0.250000,-2.625000,0.189453,-0.658691,0.726074,WAVE_IN,-
 9,-14,-3,0,0,13,2,-8
 2017-02-07 15:46:25.257,68.645020,79.368871,79.411927,-
 1.812500,0.000000,-1.937500,0.191406,-0.659668,0.710938,WAVE_IN,-
 46,-17,34,-5,0,13,46,-29
 2017-02-07 15:46:25.358,68.584801,79.416389,79.334516,-
 0.375000,0.562500,-1.000000,0.178223,-0.652832,0.721191,WAVE_IN,-
 7,-29,41,2,2,-7,-1,10
 2017-02-07 15:46:25.458,68.525095,79.508527,79.283708,-
 0.562500,1.062500,0.250000,0.177246,-0.661133,0.715820,WAVE_IN,-
 6,13,6,2,-5,-29,-6,57
 2017-02-07 15:46:25.559,68.392607,79.572067,79.266021,-
 3.312500,2.250000,1.437500,0.200195,-0.668457,0.703613,WAVE_IN,-
 3,-6,-8,-1,-1,5,-1,-11
 2017-02-07 15:46:25.660,68.039907,80.001088,79.153689,-
 15.062500,9.187500,2.062500,0.154785,-0.670410,0.708496,WAVE_IN,-
 2,0,-2,-3,-2,0,-2,-3
 2017-02-07 15:46:25.761,67.849592,80.131978,79.292877,10.000000,-
 10.187500,5.875000,0.162598,-0.774902,0.633301,REST,0,-1,-10,-
 47,-24,-2,-2,-2
 2017-02-07 15:46:25.862,68.296584,79.391391,79.960330,-
 10.062500,-6.687500,-3.500000,0.236328,-0.626953,0.761719,REST,-
 1,-2,-7,-7,-5,-1,-1,0
 2017-02-07 15:46:25.962,68.024282,79.078112,79.806514,-
 5.000000,3.375000,-2.562500,0.201660,-0.718262,0.735352,REST,-1,-
 2,-3,-3,-1,-1,-1,-1
 2017-02-07
 15:46:26.062,68.036396,79.234310,79.767669,1.375000,1.000000,0.31
 2500,0.175781,-0.670898,0.695313,REST,-1,-1,-1,-1,1,0,0,-2
 2017-02-07 15:46:26.162,68.046915,79.314392,79.748190,-
 0.312500,0.187500,-0.062500,0.185059,-0.676758,0.707520,REST,-
 1,0,-1,-3,-1,-2,-1,-2
 2017-02-07 15:46:26.262,68.050171,79.315302,79.747652,-
 0.812500,0.500000,-0.625000,0.184082,-0.677734,0.700684,REST,0,-
 3,-1,-1,1,1,0,-1
 2017-02-07
 15:46:26.363,68.032627,79.357309,79.724612,0.625000,0.312500,-
 0.437500,0.173340,-0.674805,0.697266,REST,-2,-1,-1,-1,-2,-1,0,0
 2017-02-07 15:46:26.463,68.028835,79.358853,79.728405,-1.000000,-
 0.250000,-0.125000,0.183594,-0.679688,0.701172,REST,-1,0,0,-1,0,-
 1,0,-1
 2017-02-07 15:46:26.564,68.011089,79.341418,79.744144,-0.125000,-
 1.062500,0.375000,0.179688,-0.677734,0.704102,REST,0,-1,-2,0,-1,-
 2,-1,-1

2017-02-07 15:46:26.665,68.027180,79.312759,79.783931,1.250000,-
 1.875000,0.187500,0.181152,-0.684082,0.714844,REST,-2,-1,-1,-2,-
 2,-1,-1,-1
 2017-02-07
 15:46:26.765,68.045655,79.371602,79.799096,0.437500,2.062500,1.93
 7500,0.182617,-0.681641,0.715332,REST,0,-2,-2,-1,-2,-2,-1,-1
 2017-02-07
 15:46:26.865,68.108594,79.863939,79.733572,1.687500,4.875000,2.25
 0000,0.171875,-0.683594,0.718262,REST,-2,-1,-1,-1,1,-2,-1,-1
 2017-02-07
 15:46:26.966,68.229931,80.258453,79.685837,2.562500,3.500000,2.12
 5000,0.164551,-0.670410,0.709961,REST,1,-3,-1,0,-1,-1,0,0
 2017-02-07
 15:46:27.067,68.339293,80.769366,79.609556,0.625000,4.937500,2.06
 2500,0.154297,-0.668945,0.709961,REST,0,0,1,0,-2,-2,-1,-1
 2017-02-07
 15:46:27.167,68.391107,81.306166,79.482931,0.125000,6.437500,2.06
 2500,0.150879,-0.667480,0.727539,REST,-1,-2,0,0,-2,-2,-2,-1
 2017-02-07 15:46:27.268,68.273694,82.224490,79.089481,-
 8.375000,19.687500,1.187500,0.159668,-0.657227,0.707520,REST,-1,-
 1,6,-2,2,0,-1,-1
 2017-02-07 15:46:27.368,68.258175,83.792431,80.186119,82.812500,-
 12.187500,45.687500,-0.226074,-0.942383,0.650879,REST,-19,-
 16,59,57,22,13,4,-1
 2017-02-07 15:46:27.469,68.633591,83.522591,79.714170,-
 76.250000,-16.562500,8.500000,0.145996,-
 0.923828,0.686035,REST,1,41,-108,-128,30,5,-2,3
 2017-02-07
 15:46:27.570,69.689746,83.309291,80.078116,2.687500,0.375000,-
 8.500000,0.101074,-0.603516,0.745605,WAVE_OUT,8,2,0,64,-8,-9,0,2
 2017-02-07 15:46:27.670,69.549887,82.586315,79.975725,-8.187500,-
 1.500000,-0.500000,0.092285,-
 0.657227,0.748047,WAVE_OUT,10,20,4,16,10,6,5,4
 2017-02-07 15:46:27.770,69.428195,82.577672,79.988457,-
 0.312500,0.750000,1.937500,0.119141,-
 0.648926,0.762207,WAVE_OUT,2,63,-61,3,-18,-6,-1,-1
 2017-02-07
 15:46:27.870,69.388455,82.757798,80.016843,0.312500,2.000000,2.25
 0000,0.118652,-0.665527,0.749512,WAVE_OUT,4,40,101,50,40,10,8,5
 2017-02-07 15:46:27.970,69.482345,82.978898,80.049264,5.187500,-
 0.937500,-1.312500,0.123047,-0.657715,0.746582,WAVE_OUT,-4,-52,-
 45,-84,-29,-7,-5,-2
 2017-02-07
 15:46:28.070,69.513611,83.062197,80.003594,0.500000,1.000000,-
 1.187500,0.123535,-0.642578,0.747559,WAVE_OUT,-7,-28,-35,-85,-
 33,-3,-3,-4
 2017-02-07 15:46:28.171,69.530626,83.088616,79.979874,-0.125000,-
 0.312500,-1.125000,0.122070,-
 0.646484,0.749023,WAVE_OUT,1,21,55,17,12,0,-7,1
 2017-02-07
 15:46:28.271,69.579454,83.150871,79.976620,2.062500,0.875000,-
 1.375000,0.123535,-0.629883,0.751953,WAVE_OUT,-11,2,-44,-53,-14,-
 5,-8,-8
 2017-02-07
 15:46:28.372,69.534823,83.181049,79.940291,1.062500,1.500000,-
 1.375000,0.115723,-0.646484,0.765137,WAVE_OUT,3,6,-53,-73,3,5,2,2

2017-02-07
 15:46:28.473,69.540830,83.296136,79.869972,2.937500,2.250000,-
 1.250000,0.128906,-0.649414,0.762207,WAVE_OUT,9,34,77,22,7,1,0,2
 2017-02-07 15:46:28.574,69.527630,83.448576,79.818852,-
 3.250000,2.000000,0.500000,0.123047,-0.649414,0.753418,WAVE_OUT,-
 6,11,-11,-49,-34,-9,-4,-5
 2017-02-07 15:46:28.674,69.518366,83.563432,79.756161,-
 0.875000,1.062500,-0.375000,0.115723,-
 0.654297,0.744141,WAVE_OUT,4,24,61,-22,11,3,1,0
 2017-02-07
 15:46:28.774,69.506658,83.556414,79.753078,0.375000,0.375000,-
 0.937500,0.105469,-0.652832,0.757324,WAVE_OUT,-3,-17,-
 95,6,7,2,2,-1
 2017-02-07
 15:46:28.874,69.505933,83.563299,79.732772,0.062500,0.875000,-
 0.562500,0.107910,-0.648926,0.755859,WAVE_OUT,-7,9,66,82,18,-1,-
 17,-7
 2017-02-07 15:46:28.974,69.504259,83.586802,79.724811,-
 0.687500,1.000000,-0.312500,0.107422,-
 0.650391,0.757813,WAVE_OUT,2,-16,0,19,1,3,5,3
 2017-02-07
 15:46:29.074,69.524718,83.619880,79.707811,1.125000,0.437500,-
 1.437500,0.108887,-0.654297,0.756348,WAVE_OUT,1,-1,65,76,23,-
 1,0,0
 2017-02-07
 15:46:29.174,69.544109,83.709835,79.676598,1.125000,0.812500,-
 0.625000,0.101074,-0.637207,0.753906,WAVE_OUT,0,-53,-
 26,55,7,5,39,-1
 2017-02-07
 15:46:29.274,69.508962,83.758263,79.659420,0.437500,0.875000,0.18
 7500,0.097168,-0.656250,0.751953,WAVE_OUT,6,68,119,-15,2,-1,-5,2
 2017-02-07
 15:46:29.374,69.525474,83.783092,79.643505,0.312500,0.250000,-
 0.375000,0.108398,-0.653809,0.747070,WAVE_OUT,3,-5,-64,-14,-10,-
 3,4,3
 2017-02-07 15:46:29.474,69.526883,83.811759,79.630729,-
 0.875000,1.437500,-0.062500,0.100098,-
 0.633789,0.745605,WAVE_OUT,5,5,19,7,11,15,78,9
 2017-02-07 15:46:29.574,69.526784,83.891808,79.596697,0.062500,-
 0.250000,0.937500,0.097168,-0.645020,0.750488,WAVE_OUT,-1,8,-63,-
 92,-36,-12,-13,-1
 2017-02-07 15:46:29.675,69.529409,83.953267,79.566731,-
 0.500000,0.625000,1.062500,0.108887,-
 0.655762,0.754883,WAVE_OUT,1,-43,-53,-29,-2,-13,-17,-8
 2017-02-07 15:46:29.776,69.526761,84.011978,79.506058,-
 2.000000,0.500000,-0.500000,0.105957,-
 0.655762,0.737793,WAVE_OUT,-18,-32,-10,61,31,6,-1,-2
 2017-02-07 15:46:29.876,69.520255,84.044056,79.462329,-
 0.312500,1.000000,-0.250000,0.106445,-
 0.649414,0.747559,WAVE_OUT,-3,-12,21,-90,10,0,-5,-4
 2017-02-07 15:46:29.976,69.513235,84.112372,79.426481,-
 1.937500,0.812500,0.125000,0.086426,-0.661621,0.754395,WAVE_OUT,-
 1,30,79,-16,-29,-5,-1,-3
 2017-02-07
 15:46:30.076,69.509916,84.153294,79.392635,0.875000,1.312500,-

```
0.187500,0.095215,-0.647461,0.753418,WAVE_OUT,2,7,-22,13,-4,-5,-
6,-2
2017-02-07 15:46:30.176,69.501402,84.165028,79.382855,-
0.250000,0.437500,0.312500,0.084961,-0.665039,0.754395,WAVE_OUT,-
7,-14,-47,-57,-5,2,1,-3
2017-02-07
15:46:30.276,69.500466,84.173824,79.384921,1.812500,0.250000,-
0.187500,0.100098,-0.653320,0.753906,WAVE_OUT,3,38,99,72,-2,-2,-
3,-1
2017-02-07 15:46:30.377,69.497764,84.158481,79.376215,-
0.250000,0.375000,-0.375000,0.104492,-
0.647461,0.752441,WAVE_OUT,6,26,-12,3,-1,5,1,1
2017-02-07 15:46:30.477,69.414142,84.242232,79.381970,-
3.625000,1.750000,0.375000,0.105957,-
0.664063,0.750977,WAVE_OUT,0,-5,-16,-10,1,0,1,0
2017-02-07 15:46:30.577,69.040650,84.921104,79.143687,-
8.625000,14.000000,2.937500,0.097168,-0.672363,0.756836,REST,-4,-
1,-5,-4,-1,-3,-2,-2
2017-02-07 15:46:30.677,68.946465,85.630484,78.903441,-
1.312500,7.062500,-1.500000,0.069336,-
0.616211,0.735840,REST,5,9,3,2,2,20,98,-17
2017-02-07 15:46:30.777,68.288309,85.780966,78.485918,-
12.312500,-0.312500,-7.062500,0.055176,-0.694336,0.661621,REST,-
11,-5,-2,-2,-3,0,-1,-1
2017-02-07 15:46:30.877,67.885068,85.242532,78.725908,-4.062500,-
6.812500,0.875000,0.080566,-0.688965,0.726074,REST,-2,-1,-2,0,-
2,-1,-7,-1
2017-02-07 15:46:30.977,67.936293,84.975447,78.831222,1.125000,-
1.125000,-1.062500,0.096680,-0.694336,0.754883,REST,-1,0,0,0,-
1,1,-3,0
2017-02-07
15:46:31.077,68.021794,84.911594,78.792897,1.000000,0.937500,-
0.125000,0.088379,-0.700195,0.709473,REST,-2,-1,0,-1,0,1,1,0
2017-02-07 15:46:31.179,68.022152,84.993725,78.780767,-0.437500,-
0.187500,-0.250000,0.077148,-0.682617,0.706055,REST,0,-1,-2,-1,-
2,-1,-2,-1
2017-02-07 15:46:31.279,67.970274,84.894127,78.798789,-1.062500,-
2.187500,-0.625000,0.089355,-0.689941,0.724121,REST,-1,-1,-1,0,-
1,-1,-1,-2
2017-02-07 15:46:31.379,67.972519,84.778783,78.824935,-0.187500,-
0.562500,-0.250000,0.084961,-0.692383,0.708984,REST,0,0,-1,-2,-
1,-3,0,-1
2017-02-07 15:46:31.479,67.970169,84.740207,78.844748,0.375000,-
1.000000,0.062500,0.091309,-0.688477,0.709961,REST,-2,-1,-1,-1,-
1,0,-2,-2
Exiting...
```


Appendix B. Example CSV File Output

```

YYYY-MM-DD
HH:MM:SS.SSS,ROLL,PITCH,YAW,GYRO_X_DEG/SEC,GYRO_Y_DEG/SEC,GYRO_Z_
DEG/SEC,ACCEL_X_G,ACCEL_Y_G,ACCEL_Z_G,POSE,EMG_CH1,EMG_CH2,EMG_CH
3,EMG_CH4,EMG_CH5,EMG_CH6,EMG_CH7,EMG_CH8
2017-02-07 15:46:24.052,69.111894,78.690268,80.775977,-
0.375000,0.625000,1.250000,0.190918,-0.654297,0.721680,REST,1,0,-
2,-2,-3,-1,-1,-1
2017-02-07 15:46:24.154,69.066327,78.880307,80.838109,-
0.875000,0.312500,2.312500,0.187500,-0.654297,0.720215,REST,-1,-
2,-1,-2,-2,-1,-1,0
2017-02-07 15:46:24.255,69.195277,79.016308,80.965627,14.312500,-
5.375000,-0.687500,0.166504,-0.614258,0.745605,REST,72,-9,-3,-
12,-6,-30,1,45
2017-02-07 15:46:24.355,68.443448,78.639507,79.748023,-
83.750000,-14.062500,0.375000,0.422852,-1.167969,0.384766,REST,-
36,-74,0,8,9,-7,95,-98
2017-02-07
15:46:24.455,68.955867,79.102875,79.725088,13.187500,2.875000,-
2.000000,0.173828,-0.701660,0.739258,WAVE_IN,-
11,7,33,12,8,31,70,-37
2017-02-07 15:46:24.555,68.851457,79.555237,79.805152,-
0.375000,2.125000,0.937500,0.152344,-
0.671875,0.721680,WAVE_IN,73,27,-3,1,-1,-38,14,-11
2017-02-07 15:46:24.656,68.875371,79.537099,79.807765,-
2.937500,1.187500,-0.062500,0.189941,-
0.632324,0.735352,WAVE_IN,18,14,-4,-3,-8,-19,-43,-48
2017-02-07
15:46:24.757,68.804416,79.635662,79.740990,0.562500,1.875000,1.68
7500,0.174805,-0.672852,0.735840,WAVE_IN,-23,-12,0,-3,0,-18,12,-
84
2017-02-07 15:46:24.857,68.903215,79.756034,79.743440,-
1.062500,0.937500,-0.687500,0.176758,-
0.663086,0.734863,WAVE_IN,33,-11,31,6,7,2,-28,56
2017-02-07 15:46:24.957,68.850674,79.703714,79.696705,-
3.125000,0.125000,-1.687500,0.183594,-0.670898,0.745117,WAVE_IN,-
47,-12,-113,-9,-11,-70,-32,-33
2017-02-07 15:46:25.057,68.800025,79.665062,79.666306,-
3.187500,0.375000,-1.812500,0.182617,-
0.650879,0.733887,WAVE_IN,38,-17,29,-5,-6,12,2,-5
2017-02-07 15:46:25.157,68.713604,79.552580,79.573293,-
3.125000,0.250000,-2.625000,0.189453,-0.658691,0.726074,WAVE_IN,-
9,-14,-3,0,0,13,2,-8
2017-02-07 15:46:25.257,68.645020,79.368871,79.411927,-
1.812500,0.000000,-1.937500,0.191406,-0.659668,0.710938,WAVE_IN,-
46,-17,34,-5,0,13,46,-29
2017-02-07 15:46:25.358,68.584801,79.416389,79.334516,-
0.375000,0.562500,-1.000000,0.178223,-0.652832,0.721191,WAVE_IN,-
7,-29,41,2,2,-7,-1,10
2017-02-07 15:46:25.458,68.525095,79.508527,79.283708,-
0.562500,1.062500,0.250000,0.177246,-0.661133,0.715820,WAVE_IN,-
6,13,6,2,-5,-29,-6,57
2017-02-07 15:46:25.559,68.392607,79.572067,79.266021,-
3.312500,2.250000,1.437500,0.200195,-0.668457,0.703613,WAVE_IN,-
3,-6,-8,-1,-1,5,-1,-11

```

2017-02-07 15:46:25.660,68.039907,80.001088,79.153689,-
 15.062500,9.187500,2.062500,0.154785,-0.670410,0.708496,WAVE_IN,-
 2,0,-2,-3,-2,0,-2,-3
 2017-02-07 15:46:25.761,67.849592,80.131978,79.292877,10.000000,-
 10.187500,5.875000,0.162598,-0.774902,0.633301,REST,0,-1,-10,-
 47,-24,-2,-2,-2
 2017-02-07 15:46:25.862,68.296584,79.391391,79.960330,-
 10.062500,-6.687500,-3.500000,0.236328,-0.626953,0.761719,REST,-
 1,-2,-7,-7,-5,-1,-1,0
 2017-02-07 15:46:25.962,68.024282,79.078112,79.806514,-
 5.000000,3.375000,-2.562500,0.201660,-0.718262,0.735352,REST,-1,-
 2,-3,-3,-1,-1,-1,-1
 2017-02-07
 15:46:26.062,68.036396,79.234310,79.767669,1.375000,1.000000,0.31
 2500,0.175781,-0.670898,0.695313,REST,-1,-1,-1,-1,1,0,0,-2
 2017-02-07 15:46:26.162,68.046915,79.314392,79.748190,-
 0.312500,0.187500,-0.062500,0.185059,-0.676758,0.707520,REST,-
 1,0,-1,-3,-1,-2,-1,-2
 2017-02-07 15:46:26.262,68.050171,79.315302,79.747652,-
 0.812500,0.500000,-0.625000,0.184082,-0.677734,0.700684,REST,0,-
 3,-1,-1,1,1,0,-1
 2017-02-07
 15:46:26.363,68.032627,79.357309,79.724612,0.625000,0.312500,-
 0.437500,0.173340,-0.674805,0.697266,REST,-2,-1,-1,-1,-2,-1,0,0
 2017-02-07 15:46:26.463,68.028835,79.358853,79.728405,-1.000000,-
 0.250000,-0.125000,0.183594,-0.679688,0.701172,REST,-1,0,0,-1,0,-
 1,0,-1
 2017-02-07 15:46:26.564,68.011089,79.341418,79.744144,-0.125000,-
 1.062500,0.375000,0.179688,-0.677734,0.704102,REST,0,-1,-2,0,-1,-
 2,-1,-1
 2017-02-07 15:46:26.665,68.027180,79.312759,79.783931,1.250000,-
 1.875000,0.187500,0.181152,-0.684082,0.714844,REST,-2,-1,-1,-2,-
 2,-1,-1,-1
 2017-02-07
 15:46:26.765,68.045655,79.371602,79.799096,0.437500,2.062500,1.93
 7500,0.182617,-0.681641,0.715332,REST,0,-2,-2,-1,-2,-2,-1,-1
 2017-02-07
 15:46:26.865,68.108594,79.863939,79.733572,1.687500,4.875000,2.25
 0000,0.171875,-0.683594,0.718262,REST,-2,-1,-1,-1,1,-2,-1,-1
 2017-02-07
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1,0,-2,-2

List of Symbols, Abbreviations, and Acronyms

| | |
|-----|-----------------------------------|
| API | application programming interface |
| CSV | comma-separated value |
| dll | dynamic-link library |
| EMG | electromyography |
| JAR | Java archive |
| LSL | lab streaming layer |
| OS | operating system |
| SDK | software development kit |
| XDF | extensible data format |

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